APPLICATION OF PAPER SLUDGE ASH IN CONSTRUCTION INDUSTRY – A REVIEW

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ABSTRACT

Cement manufacturing industry is one of the foremost carbon dioxide emitting sources besides deforestation and burning of fossil fuels and concrete industry is one of the largest consumers of natural virgin materials. The global cement industry contributes about 7% of greenhouse gas emission to the earth's atmosphere. In order to reduce environmental effects associated with cement manufacturing and constantly consuming natural resources, there is a need to develop alternative binders to make concrete industry sustainable. Paper sludge ash is a material that is considered as an alternative binder to make concrete as like as GGBS, Rice Husk, Glass Powder, Fly ash, Phospogypsum etc. Paper mill sludge is a major pecuniary and environmental problem for the paper and board Portland cement ingredients. Potential applications for paper sludge ash include use in cement production. Current applications include waste neutralization, cattle bedding and land spreading. In Bangladesh there is produce a thousands of ton paper sludge in every year. This paper sludge has a great impact on environment. For those reasons to ease environmental effect and produce low cost concrete, it is most essential to develop profitable building materials from paper sludge ash. This work reviews the different environmental impacts associated with Paper sludge storage, disposal and investigate to use this materials as a binding materials in concrete by replacement of cement industry.

Keywords: *Paper sludge, Cement, Waste management, Environment pollution*

1. INTRODUCTION

Cement manufacturing industry is one of the foremost carbon dioxide emitting sources besides deforestation and burning of fossil fuels and concrete industry is one of the largest consumers of natural virgin materials. The sustainable industrial production in the 21st century are facing two major problems that reducing carbon dioxide emissions and recycling of waste materials. In order to reduce cost and environmental effect construction industry and cement manufacturing company needs an alternative source for full filling the demand of sustainable construction materials. Due to increasing population a large demand placed on building construction has caused an enduring regional shortage of building materials. Consequently, the Civil engineers have been challenged to renovate solid waste to useful building and construction materials. There are several numbers of waste materials available to incorporate these materials in construction industry. Alleman and Berman,(1984); Liaw et al.,(1998) ; Chiang et al., (2000); Tay et al., (2002); Singh, (2002); Show and Tay (2002); Yague et al.,(2002); Cusido et al., (2003); Weng et al., (2003); Liew et al., (2004); Huang et al. (2005); Shih et al. (2004); Vieira et al., (2006); Erol et al., (2008); Monteiro et al., (2008); Cultrone and Sebastián, (2009); Chiang et al., (2009); Montero et al., (2009) found that potential uses of paper processing residues, Kraft pulp production residue, welding flux slag and waste paper pulp, fly ash, textile effluent treatment plant sludge, polystyrene foam, plastic fibre, straw, polystyrene fabric, cotton waste, Phosphogypsum, Glass powder, cigarette butts, rice husk ash, granulated blast furnace slag, rubber, limestone dust and wood saw dust, dried sludge collected from an industrial waste water treatment plant, processed waste tea, petroleum effluent treatment plant sludge materials could be used in construction industry. Paper sludge ash is a material that is considered as an alternative source of sustainable waste material. There are thousands of tons paper sludge produced in every year. Paper mill sludge is a key economic and environmental delinquent for the paper and board industry. The material is a by-product of the de-inking and re-pulping of paper. Paper sludge ash can be obtained by incinerating paper sludge at approximately 750^0C observed by de la Villa et al., (2006). The resultant fly ash combined with reactive silica and alumina (in the form of metakaolin) as well as lime (CaO). And this is chemically similar the Portland cement ingredients. Bai et al., (2003) observed that the presence of CaO in WPSA has both negative and positive concerns for the use of WPSA as a hydraulic binder. The main destructive aspect is the enlargement due to the hydration of CaO to $Ca(OH)_2$, which outcomes in unsoundness

if it occurs after setting. Boni et al., (2004) investigated environmental quality of paper sludge .They found that the primary paper sludge does not epitomize a major hazard for the environment in terms of heavy metal release. Many researchers have investigated about the potential uses of paper sludge ash in construction industry, cement manufacturing company, ceramic and glass production etc. Honeycutt et al., (1988); King, (1984) found that Paper mill sludge initially caused a net immobilization of nitrogen on agricultural land if paper mill sludge applying with a high C:N ratio. Pera and Amrouz, (1998); Frías et al., 2004; Banfill and Frías, (2007); Vegas et al., (2006) described that considering environmental point of view, paper sludge wastes could be recycled obtain metakaolinite. Previous studies have demonstrated having the good qualities of these calcined clay wastes as highly pozzolanic materials.

Frías et al. (2008) investigated calcination of art paper sludge waste for the use as a supplementary cementing material. The clay sludge rich in kaolinite and Talc was calcined at 600, 650 and 700°C between 2 and 5 h. This paper found that a good supplementary cementing material for manufacture of blended cements when calcination at 650°C for 2 h. Liaw et al., (1998), Marcis et al., (2005) and Ernstbrunner, (2007) found that a possible reprocess of the paper mill sludge is its blending with natural raw materials haul out from the ores in the manufacture of bricks or cements. Kinuthia et al.,(2001) , Veerapan et al.,(2003), Bai et al.,(2008), Chaipanich et al.,(2005) showed that by combining Waste Paper Sludge Ash(WPSA) with Ground Granulated Blast Furnace Slag(GGBS) hydration products can be achieved by improving its formation. Pera and Amrouz (1998) studied the production of Metakaolin by calcining paper sludge in the temperature range of 700°C to 800°C and it was shown that Kaolinite mineral in the sludge converted to Metakaolin by investigating the chemistry and mineralogical alignment. However no Metakaolin is detected in WPSA due to the much higher combustion temperatures.

In this study it is tried to discuss the properties of Paper sludge ash along with different studies associated with the potential use of it for sustainable development.

2. CHARACTERISTICS OF PAPER SLUDGE ASH

2.1 Physical properties

Paper mill sludge is composed of mineral fillers, small cellulose fibres, water, inorganic salts and organic compounds .Paper sludge ash is produced by incinerating waste paper sludge from the paper manufacturing process. Mochizuki et al.,(2003) studied its pH ranges widely from a nearly neutral level to around 12 depending on its composition and the particle density is around 2.2 to 2.9(g/cm^3), the maximum dry density is 0.65 to 0.95(g/cm^3). Corinaldesi et al.,(2010) found its water absorption capacity around 25% and Specific gravity in saturated surface dried(SSD) condition is 1720(kg/m^3) and also found Paper sludge ash passing 75 µm sieve is 80%. Monosi et al.,(2012) found the bulk density of the paper ash is equal to 1200 kg/m^3 and was lighter than ordinary sand (that predictably ranges from 2500 to 2600 kg/m^3) and binders (2100-3100 kg/m^3) generally used in the production of mortar. Tay (1987) found the average specific gravity of sludge ash is 2.81. On the other hand Ahmad et al.,(2013) found the specific gravity of paper sludge ash is 2.6. Khanbilvardi et al.,(1995) described that the sludge ash is inorganic ,water content about 28% and bulk specific gravity 1.83. Ishimoto et al.,(2000) scrutinize that paper sludge contains 60% water and 40% solids. And solids contains 30% ash, others is ignition loss. Liaw et al., (1998) found average moisture content in paper sludge is 75.40% and ignition loss is 70.11% and after co-generation of ashes ignition loss is 19.63%.

2.2 Chemical properties

The principal constituents present in Waste Paper Sludge Ash (WPSA) are lime (CaO) and silica (SiO_2). The amounts of the other major elements were low (less than 2%), except for MgO (4%). Therefore it contains also Aluminium trioxide (Al_2O_3) ,Ferric trioxide(Fe_2O_3) ,Magnesium oxide(MgO) ,Sulphate(SO_3) ,Potassium oxide(K_2O) etc. The volume/weight can be reduced by dewatering at low temperature (<200°C) and incineration at high temperature (>800°C). During incineration, organic compounds are burned at temperatures of around 350 to 500°C, whereas mineral fillers and inorganic salts are transformed into the corresponding oxides at higher temperatures (>800°C). CaO, Al_2O_3, MgO, and SiO_2 are the most abundant oxides in Paper sludge Ash (PSA) found by Liaw et al., (1998). Bai et al., (2003) observed that the presence of CaO in WPSA has both negative and positive concerns for the use of WPSA as a hydraulic binder. The main destructive aspect is the enlargement due to the hydration of CaO to $Ca(OH)_2$, which outcomes in unsoundness if it occurs after setting. Mozaffari et al.,(2009) scrutinized when the presence of lime could be fascinating from the point of view of using the ash as a hydraulic binder. The fast hydration of lime would give high alkalinity to the solution, which

could be used to advantage to activate pozzolanic materials or Ground granulated blast furnace slag (GGBFS) in the case of WPSA. Here is given a table of chemical composition for Paper Sludge Ash (figure 1).

Oxides(%)	CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	K_2O	TiO_2	P_2O_5	MnO	SO_3	Na_2O	LOI
Segui et al., 2012	45.5	28.0	13.2	1.3	4.0	0.7	0.7	0.4	0.1	1.3	0.4	5.7
Bai et al.,2003	43.51	25.70	18.86	0.87	5.15	1.31	0.68	0.52	0.04	1.05	1.56	1.2
Frías et al.,2008 (700^0 C,2h)	40.21	22.32	14.55	0.56	2.35	0.37	0.26	0.18		0.32	0.09	18.52
Vegas et al.,2009 (650^0C,2h)	36.5	21.6	14.4	0.5	2.4	0.4	0.3	0.2		0.3	0.1	23.2
Banfill and Frías,2007 (700^0C,2h)	31.40	30.20	18.00	0.7	2.7	0.32	0.35			0.27	0.21	14.53

Figure 1: Chemical composition of paper sludge ash . adopted from Segui et al., 2012

2.3 Mineralogical composition

Editing (1985) Paper sludge contains very small quantities of minerals, such as kaolinite and calcium carbonate, used as coating agents for ensuring a smooth paper surface. The quantity of coating agents varies depending on the type of paper, but is generally between 5 g/m^2 to $20g/m^2$. The minerals contained in the WSA were: gehlenite ($Ca_2Al2_2SiO_7$), lime (CaO), calcite ($CaCO_3$), quartz (SiO_2), merwinite ($Ca_3Mg(SiO_4)_2$) and α′-Ca_2SiO_4. Bai et al.,(2003) described that Gehlenite is the major mineral and gives the strongest diffraction pattern when together with lime. And also assumed that the presence of bredigite ($Ca_{14}Mg_2(\text{-}SiO_4)_8$) is possible but it could not be distinguished it from α′-Ca_2SiO_4 because these two minerals have very parallel XRD patterns. Frías et al., (2008); García et al.,(2008); Villa et al., (2007) investigated that the results of the XRD analysis are very important for the valorization of Waste Paper Sludge Ash(WPSA) as a hydraulic binder. WPSA contains minerals that are potentially reactive: lime (CaO), mayenite ($C_{12}Al_{14}O_{33}$) and α′-Ca_2SiO_4. In divergence to other calcined paper sludges that have pozzolanic properties due to the presence of metakaolin, there is no purpose for the WPSA under study to have pozzolanic properties.

3. LITERATURE REVIEW

Suzuki et al., (1997) produce ceramic samples by accumulation limestone to sewage sludge incinerated ash. The sludge ash is offered as fine dust, so it can be straight mixed with other ceramic paste machineries. Ceramic samples containing 50% sludge ash showed strength, acid resistance and absorption coefficient within the ordinary range for ceramic. Kinuthia et al., (2001) investigated the compressive strength and workability of concrete using Waste paper sludge ash and GGBS. This paper concluded that it is possible to combine Waste Sludge Ash (WSA) and GGBS, a waste product and a by-product respectively, to produce a binder without combining Portland cement.

Weng et al., (2003) inspected bricks produced from industrial waste water treatment plant sludge and all required properties test were implemented. Results illustration that the quality of the product depends on sludge proportion and the firing temperature. Strength of bricks with up to 20% sludge content at temperature assortments of 960-1000°C met the required Chinese standards. The leaching result on the product illustrations a low metal ooze level.

Monzo et al., (2004) scrutinized the potential use of Sewage Sludge Pellets (SSP) as auxiliary for material in raw mix formulation in manufacturing process of Portland cement. Sewage Sludge Ash (SSA) was relieved for cement at 15 and 30% by weight in mortar. The results signposted that the mortar containing 15% of (SSA) has a compressive strength similar to reference mortar. When (SSA) content increased up to 30%, a significant lessening was detected, 11% of cement clinker dry weight was substituted with (SSP) without any problem or larger differences paralleling to cement made with normal clinker contents. Fontes et al.,(2004) evaluated the potentiality of using sewage sludge ash(SSA) as mineral stabilizer in cement mortars and high enactment concrete. This study found that the 7 days compressive strength of mortars is higher than reference mixture when cement is replaced by 10-30% of SSA and same strength at 28 days. It also found high performance concrete at 28 days when replacing 5-10% of OPC by SSA.

Bujulu et al.,(2007) studied the re-using of waste paper sludge ash as a binder in stabilization of problematic and soft soils. This paper found that chemical and mineralogical analyses exposed that WSA will have no extreme

penalties in terms of pollution of soil and ground water. This paper showed that increasing the quantity rate in lime-WSA mixtures from 100 kg/m3 to 150 kg/m3 has negative effects to the mechanical properties of the mixtures.

Dunster (2007) investigated a case study designates the potential use of mill paper sludge and its offshoots, as ingredients in Portland cement manufacture. This study concluded that the Paper sludge and paper sludge ash are hypothetically useful products in the construction of cement and in blended cement.
V. Mymrin et.,(2009) inspected to a new construction material which was based on paper production sludge and lime production waste. This paper demonstrated that paper production sludge can be used as the main component raw material, up to 50-60% by mass without drying and backing for the manufacture of components with less environment impact hand bricks and blocks. It found that obtained materials on the 28th day have uniaxial resistance strength up to 15.7 MPa. It also concluded that the application of the method can ominously decrease natural construction materials abstraction and improve the environment situation of industrial regions.
Corinaldesi et al.,(2010) studied about paper mill sludge ash as supplementary uses of cementious materials. This study found that 5% of paper ash containing in mortars exhibited higher compressive strength at 28 days. It also concluded that mechanical properties of concrete show positive effect if cement is replaced by less than 10% paper sludge ash.

Ismail et al.,(2010) scrutinized to manufacture of Bricks From Paper Sludge And Palm Oil Fuel Ash(POFA). This paper inspected the results of laboratory work carried out on these by-products in order to evaluate application performance. This paper found that Bricks fabricated by incorporating 20% paper sludge and 20% POFA into cement provide adequate compressive strength ,thereby illustrating significant potentialities to serve as masonry unit elements and also found Paper sludge-POFA brick has about 26.1% weight reduction when compared with normal brick.

Balwaik et al.,(2011) Utilized of Waste Paper Pulp(a soft, wet, shapeless mass of material) by Partial Replacement of Cement in Concrete. The cement has been replaced by waste paper sludge accordingly in the range of 5% to 20% by weight for M-20 and M-30 mix. This paper investigated some parameter and found that slump increased up to 5% replacement of cement and above 5% the slump decreased as the paper pulp content in the concrete mixtures was increased. It also found that the splitting tensile, compressive and flexural strength increased up to 10% addition of waste paper pulp and further increased in waste paper pulp reduces the strengths progressively. It concluded that 5 to 10 % replacement of waste paper pulp to cement is most suitable mix proportion and suggested that Uses of waste paper pulp in concrete can save the pulp and paper industry disposal costs and produce a 'greener' concrete for construction.

Frías et al., (2011) utilized the paper sludge in cement. This paper manufactured binary and ternary cements. it is recommended that the percentage should be limited to around 10% clinker for paper sludge calcined at 700ºC for binary cements and reduce setting times, loss of workability and excessive total drying shrinkage. In the manufacture of ternary cements that contain sludge calcined at 700ºC and fly ash, the percentage of clinker replaced by the addition of these minerals should not exceed 21% and it ensures that the workability of the mixture is not adversely affected.

Dabwan et al.,(2012) investigated about Utilization of Paper Sludge Wastes for Treatment of Wastewater from Food Processing Industries. In this paper Waste paper sludge was provided from the paper mill waste water treatment plant. The developed inorganic coagulant was applied into the treatment of wastewater from Japanese food processing industries. it concluded that The wastewater treatment by the coagulation with Agoclean–P inorganic coagulant, which consisted of paper sludge ash wastes, appears to become one of very effective methods for the wastewater from food processing industries. And also concluded that the continuous Hi–Biah–System (HBS) treatment system with inorganic coagulant Agoclean–P can be applied into 5m3/h of wastewater.

Monosi et al.,(2012) conducted to re-use of paper mill ash in plaster blends .in this study concluded that paper ash can be used as whole or partial replacement of the inert in finishing plaster . it also found that the best piece of this material is its lightweight property that gives fresh mortar proper consistency and facilitates its solicitation both by hand (trowel) and by plaster machines.

Arsenovic et al., (2012) reconnoitered the possibilities of using industrial sludge in masonry industry and the environmental possessions of leaching potentials were considered. Sludge used was collected from a hot-dip galvanizing course after waste water neutralization. Though it comprehends some hazardous material payable to

the presence of toxic elements, the results from leaching test shows a unimportant level after firing at 102°C. The results appearance that sludge can be used to produce biodegradable bricks.

S. Ahmad et al.,(2013) investigated to Use of Waste Paper Sludge Ash as Partial Replacement of Cement. This paper found that 10% increase in compressive strength at 7 days and 15% increase in compressive strength at 28 days for 5% replacement of cement by waste paper sludge . But Splitting tensile strength decreases with increase in waste paper sludge ash content. It also found that average weight decreases by 4.58% for mixture with 20% waste paper sludge ash content when increase in waste paper sludge ash content.
Solanki et al.,(2013) investigated the flexural strength of beams by using partial replacement of cement with fly ash and hypo sludge in concrete. Fly ash and hypo sludge is acquired as waste product from the thermal and paper industries.The replacement percentages was 0%, 10%, 20%and 30%. This paper found that the flexural strength of the concrete increases up to 11.08% when the 20% replacement of cement by fly ash. And up to 8.91% when 10% replacement of cement by hypo sludge.

Johnson et al.,(2014) reviewed about the potential uses of waste sludge in construction industry. This review study revealed that usage of various type of sludge as a raw material in construction industry is clearly reasonable without bargaining the material requirements bestowing to available standard. It can be clinched that the potential use of sludge in construction industry is an alternative to the treatment and dumping of sludge considering the huge cost and intricacy convoluted in the treatment.

4. ENVIRONMENTAL EFFECT

A series of micro and mesoporous activated carbons are produced from paper mill sludge. Activated carbon is also produced from wood, peat, coal, and wastes of vegetable origin. Lu et al.,(1996) showed that activated carbons can be produced from municipal wastewater treatment sludge. The conversion of paper mill sludge to activated carbon delivers an innovative, environmentally safe, and economically realistic solution to the problem of sludge supervision at paper mill lavatories observed by Khalili et al.,(2000).The effect of the paper sludge on the environment can be much greater. Oikari and Nakari, (1982) Studied with both bleached and unbleached Kraft pulp mill effluents (KME) and showed evidence of impaired liver function in fish exposed to these effluents. Munkittrick et al.,(1997) observed variety of responses in fish populations and these included sexual maturity, smaller gonads, changes in fish reproduction and a depression in secondary sexual characteristics. Logan & Esmaeilzaden,(1985); Honeycutt et al.,(1988) observed that numerous workers have found increases in soil pH and organic matter content following the addition of paper mill sludge(PMS) to land. Sahu (1987) and Panda & Pattraik (1990) found that due to the calcium carbonate content of PMS yield increases for a range of crops on acid soils. For a large range of crops (greenhouse, container nursery and field) the principal constriction to PMS use is Nitrogen(N) immobilization resulting in N deficiencies observed by Bellamy et al., (1995) by 10 years research programme into the use of PMS as a soil amendment. Tsai et al.,(2002) investigated the effects of the sludge feeding rate on emissions of SO_x,NO_x, and CO in a coal-sludge co-fired 103 MWth circulating fluidized bed boiler. This paper reported that emissions of SO_x and NO_x decrease with increasing the sludge feeding rate and CO shows the opposite tendency due to the decrease in combustion temperature due to a large amount of moisture in the sludge but the increase of CO secretions is slight. Authors concluded that the combustion ashes could be used as the raw materials of cement. Boni et al.,(2004) investigated environmental quality of paper sludge .They found that the primary paper sludge does not epitomize a major hazard for the environment in terms of heavy metal release.

5. POTENTIAL USES OF PAPER SLUDGE

5.1 Soil amendments

Paper mill sludge can be applied for soil amending in a great extent .Phillips et al., (1997) found De-ink paper mill sludge (DPMS) diverges in composition between mills and is very useful as a soil conditioner as having high in cellulose and low in potentially toxic compounds. Dolar et al., (1972); Gabriels (1988); Ritter et al., (1992) investigated paper mill sludges (PMS) to agricultural land as a soil modification or as a cradle of lime may be a more desirable alternative to landfill. Wysong, (1976);Mick et al., (1982); Smyser, (1982); Carter, (1983); Einspahr et al., (1984); Valente et al., 1987; Campbell et al.,(1991) investigated that paper sludge can be used in land application as a compost. Sludge mass and volume could be potentially reduced by composting processes of paper sludge. For this reasons hauling costs, degrade compounds toxic, reduce odour, inhibitory to plant growth and decrease C:N ratio. Thus nitrogen immobilization and biodegrade chlorinated organic, and harvest a more valuable material apposite for horticultural and agricultural solicitations. Dick and McCoy, (1993) described that after applying Paper sludge as compost, it has neutral PH and C:N ratio 10-30:1. O'Brien

et al.,(2002) applied paper mill sludge for growth of corn plants. They found that corn plants growth rate suppressed when amounts of paper mill sludge is increased and biomass decrease as for Nitrogen deficiency .this paper appeared that the paper sludge led to immobilization of soil-available N and P. and they recommended some strategies such as supplementing N or delaying seeding may be to eliminate deficiency symptoms and biomass suppression.

Successful use of paper mill sludge in agriculture must validate without adverse effects, that crops advantage or soil properties progress from the tallying of the sludge as a soil amendment.

5.2 Uses in construction industry

Monzo et al., (1995) studied to use Sewage Sludge Ash (SSA) in cement admixtures in mortars. This paper found that The shape of sewage sludge ash particles is not spherical and also found that the compressive strength of mortar is higher than control in 3,7,28 days curing time. It also found higher flexural strength than control. Liaw et al., (1998) studied to develop a technology for reusing the paper sludge and co-generation ashes produced by the paper industry.This paper examined some properties that water absorption rate of light weight aggregates made from paper sludge and made from co-generation ashes. It also examined the compressive strength of concrete. They concluded that the paper sludge and co-generation ashes generated from paper mill could be reused as the raw materials of light-weight aggregate and constructional brick by employing granulation and sintering procedures. Ahmadi et al.,(2001) investigated of utilization of paper waste sludge in the building construction industry. Five concrete mixes containing various contents of the waste, 0 (control mix), 3, 5, 8 and 10%, as a replacement to the fine sand. This paper found that the concrete density reduced due to the presence of waste materials and found permissible compressive strength for masonry concrete construction.it concluded that the sludge waste can be successfully utilized as a replacement for mineral fillers in concrete mixes for non-structural masonry construction. Chaipanich et al.,(2005) reported that WSA paste at standard consistence (w/b:0.65) sets very quickly and described for this reasons it is totally unsuitable for use alone as a cement in concrete or conventional mortar. For this problem active components needs to establish such as ash or having active hydration characteristics. The authors also found that for WSA–GGBS combined pastes a evident increase in the time to initial set occurred as the GGBS: WSA ratio increased. The alteration of second binder is also good indication of possible changes in the rate. And hydration products can be formed. This paper concluded that GGBS can be reduce the proportion of expansive products by consumption of CaO when added to lime bearing materials such as WSA or clay–lime systems.

Valls et al. (2005) investigated the probable usage of dry sludge as stabilizer in concrete. This paper used dried sewage sludge to reduce its humidity to a certain limit and remove microorganisms. They examined dried sludge as fine sand at percent various from 0-10% in concrete they found that dried sludge is very beneficial in concrete when sludge reacts with cement and comes to form of binding matrix, the sludge components were stabilized and quantity of leachable heavy ions was reduced compared to free dry sludge. This paper found that the compressive strength of concrete decreased as the sludge content increased. They concluded that Sludge content of 10% or more cannot be used because the setting time was delayed and the concrete mechanical properties were reduced significantly. de la Villa et al.,(2006) studied the Mineralogical and morphological changes of calcined paper sludge at different temperatures. Initially sludge is treated 700, 750 and 800 °C during 2 and 5 h and observed that initial kaolinite becomes metakaolinite. After treated to 700 °C for 2h,its pozzolanic activity observed with compare to industrial metakaolinite. This paper concluded I that the pozzolanic activity of metakaolinite is sturdily similar to the crystallinity of the original kaolinite. Banfill et al.,(2007) considered calcined paper sludge is an alternative source of metakaolin, an established complementary cementitious material. This offers a route for utilising this waste material, as an alternative to the increased environmental burden associated with the production of metakaolin from natural kaolinite resources. Frías et al.,(2008) investigated calcination of art paper sludge waste for the use as a supplementary cementing material. The clay sludge rich in kaolinite and talc was calcined at 600, 650 and 700 °C between 2 and 5 h. This paper found that a good supplementary cementing material for manufacture of blended cements when calcination at 650 °C for 2 h. Mozaffari et al.,(2009) used paper sludge ash with GGBS for investigated the strength development of the paste. They found that waste paper sludge ash(WPSA) is like a cementitious material in which some constituents hydrate faster than others and free lime with WPSA immediately react with water and provides a highly alkaline pore solution which release Al2O3 and SiO2.and also found that hydrating effect of lime could be accelerated if second by product GGBS is used .they concluded that higher strength to the hardened paste and concrete samples could be obtained by using this combination of techniques releases more lime, which is made available for hydration. Segui et al.,(2012) investigated to use paper sludge ash as a component of hydraulic binder. They found that if waste paper sludge ash use only as a binder for the construction industry there are some problem observed due to presence of lime. On the other hand they found that this is very useful in Road works, especially for the stabilization of soil. Wong et al.,(2015) tried to use waste paper sludge ash in hydrophobic concrete. This

study observed the inspiration of a super-hydrophobic powder resultant from waste paper sludge ash (PSA) on a variety of properties of pastes and concretes at water/cement ratio of 0.38 and cured for up to 28 days. This paper concluded that to enhance the resistance of concrete to water ingress super-hydrophobic PSA has significant potential as an admixture or surface coating, and therefore against a range of deterioration mechanisms. This agreements a high-value solicitation route for a waste material that can potentially heighten the durability and sustainability of concrete structures. Pera and Amrouz, (1998); Frías et al., (2004); Banfill and Frías, (2007); Vegas et al., (2006) described that considering environmental point of view, paper sludge wastes could be recycled obtain metakaolinite. Previous studies have demonstrated having the good qualities of these calcined clay wastes as highly pozzolanic materials.

It can be whispered from above discussion of potential uses of paper sludge ash in construction industry that paper sludge ash can be successfully applied in construction industry without considering any environmental hazards , but paper sludge ash alone can not be satisfied all the hydration characteristics. So, it will be better, if another by product such as GGBS, glass powder, Rice Husk Ash etc. is used with paper sludge ash as a active set retarder materials.

6. CONCLUSIONS

This review study revealed that convention of Paper sludge as a raw material in construction industry is clearly reasonable without co-operating the material requirements according to available standard. Considering the huge cost, complexity involved in the treatment and environmental factors, it can be demonstrated that the potential use of paper sludge in construction industry is an substitute to the treatment, disposal of paper sludge and it would provide ample solution to the waste problem and stimulate eco-friendly environment with a condensed or low-cost raw material. In our country, Bangladesh, Paper production industry is the main source of Paper sludge production. They sometimes sale this product in a very low price or dump them after production process. A more detailed research and development work will help to ensure a better use of this material. Considering the quality and properties of Paper sludge, industry based research work for the potential use of it will establish mutual improvement of productivity and research. Cement industry should not have to depend more on the natural gypsum for production. Environmental concern is an important issue in this regard. So, ensuring proper use of this material commands to sustainable development of the society.

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